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Water resource assessment on Maghreb using global satellite products

Gérard Beltrando[a]*, Jean - Claude Berges[b]

[a] *UMR 8586 du CNRS (PRODIG) & Université Paris Diderot, Sorbonne Paris Cité 75205 Paris France*
[b] *UMR 8586 du CNRS (PRODIG) & Université Paris 1 Panthéon Sorbonne 75005 Paris France*

Abstract

The aim of this paper is to show an inter-comparison between three main precipitation products (GPCP, 3B42, GSMaP). Their biases will be analyzed according to their estimation algorithm design and to the relative weight of primary information (infra-red or microwave satellite, rain gauges network). The comparison focuses on the accumulated precipitations and few rainy events between September and November 2010 in Maghreb, as well as on the event corresponding to the hydrological Algiers catastrophe in November 2001. It appears that, while microwave sensors are a valuable tool for precipitation measurements in most situations, they fail to properly retrieve the rainfall associated with orographic effects. These products do not allow a good estimation of rainfall for extreme events with low spatial extension.

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Keywords : Rainfall products (GPCP, 3B42, GSMaP); North-West Maghreb.

1. Introduction

The study of rainfall in many regions is often affected by insufficient data due to sparse station networks. A joint effort of the main spatial and meteorological offices allows producing a full set of global precipitation estimators, which can be used as an operational basis. These rainfall products are useful tools both to follow up of water cycle at

* Corresponding author. Tel.: +33 (0) 6 85 56 28 99; fax: none.
E-mail address: beltrando@univ-paris-diderot.fr

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the global scale and to assess precipitation rates from atmospheric models. However, at the local (operational) level, the reliability of these products is still subject to controversy, especially in areas where precipitation features are dependent of local environmental conditions.

Since 1974, with the GATE experiment and the launch of the first geostationary meteorological satellite, the remote sensing community has devoted a lot of attention to the development of satellite based rainfall estimation methods. However the availability of TRMM data from 1979 onwards introduced a dramatic shift in these algorithms design. The TRMM satellite carries precipitation radar and a passive microwave imager. Hence microwave measurements can be calibrated as rainfall intensities. In this text we will focus on three operational products: GPCP, 3B42 and GSMaP.

These three main precipitation products provide comprehensive information about rainfall at a large scale, but differ significantly when considered at a regional or local scale. These differences come from the algorithms used for each product and the objective of this paper is to investigate the factors explaining these differences at seasonal and daily scales. All these estimation methods rely on microwave imagers but they are deeply different both by the retrieval algorithms and by the strategy to integrate infra-red information. Moreover, whereas the GSMaP is a pure satellite product, the GPCP and the 3B42 apply a correction based on rain-gauges network data.

2. Material: The three rainfall products (GPCP, 3B42, GSMaP)

The present study deals with the South West Mediterranean and especially the Maghreb, a region occasionally affected by problems of water supply on parts of its territory, and even sometimes by health problems due to long periods of drought. This region is also affected by violent rainfall events generated by strong perturbations from the Atlantic Ocean or Mediterranean Sea. The topography explains that orographic convective systems are the cause of high human and material damage in densely populated areas in plains or valleys.

In this study, we use three main precipitation products (GPCP, 3B42, GSMap).

As stated before, the 3B42 rainfall estimation integrates both information of rainfall stations collected by the GPCC (Global Precipitation Climatology Center) and satellite data sensors. The GPCC rainfall maps used in this product are computed on a monthly basis and on a one-degree grid. The 3B42 produces firstly a pure satellite estimate, and, then, applies a multiplicative correction factor in order to match the mixed product with the GPCC. Therefore satellite information act as a downscaling factor from GPCC scale to 3B42 delivery scale (a daily 0.25° grid). The GPCP acts in a very similar way but computes the correction factor on a broader 2.5° grid.

- The TRMM (Tropical Rainfall Measuring Mission) 3B42 dataset (NASA classification of TRMM products) uses the microwave GPROF (Kumerow et al., 2006) rain estimates to adjust high temporal resolution (3-hourly or higher) IR rain rates, over daily gridded 0.25 x 0.25 degree lat/long boxes. The 3B42 retrieval algorithm used for this product is based on the technique by Huffman and al. (1995).
- The GPCP (Global Precipitation Climatology Project) One-Degree Daily Precipitation Data Set (1DD) provides fields of precipitation totals for October 1996 through to the delayed present. The 1DD draws upon several different data sources covering different areas of the globe. Every attempt has been made to homogenize the complete record, given the different available input sources (Huffman et al., 2001).
- The GSMaP (Global Satellite Mapping of Precipitation) product is a project promoted for a "Production of a high-precision, high-resolution global precipitation map using satellite data," (grid 0,1°C; Domain 60N - 60S) sponsored by Core Research for Evolutional Science and Technology (CREST) of the Japan Science and Technology Agency (JST) during 2002-2007. Since 2007, GSMaP project activities are promoted by the JAXA Precipitation Measuring Mission (PMM) Science Team (Aonashi et al., 2009; Ushio et al., 2009).

The satellite estimation differs deeply between the NASA and the JAXA products, both by the microwave and infrared subcomponents. Among significant differences, the JAXA microwave estimator uses a rain/no rain mask closer to TRMM precipitation radar estimations and takes into account an extra channel for the highest rainfall intensities (Seto et al., 2009). The NASA uses a simple histogram matching method to integrate infrared information, while the JAXA product relies on a more sophisticated morphing algorithm. To relate these differences to a basic statistical tradeoff, NASA products are more on the robustness side while the JAXA product focuses on accuracy. As the GSMaP performances rely deeply on the microwave retrieval, this product does not estimate rainfall when ground temperatures are below 0°C.

Grid size differs between products but it has to be noticed that basic satellite information are oversampled to some extent. Depending on satellite microwave sensor, the nadir pixel size varies from 5km to 40km. Moreover, due to geometric consideration, the actual size on the end of swath is more than twice the sub-satellite one.

3. Some results about the inter-comparison of the precipitation products

Firstly, we analyze the rainfall accumulation from September 1st to November 30th 2010 and, then, some comparisons are made for three gauge events that have affected the region.

3.1. Comparison of the accumulated September - November 2010 rainfall

A sensible difference appears between the three products, even aggregated on three months. The GPCP, which has the rougher resolution, gives the higher estimates for the whole northern littoral area, except for the western part of Middle-Atlas where the 3B2 indicates a high rainfall spot (Fig. 1).

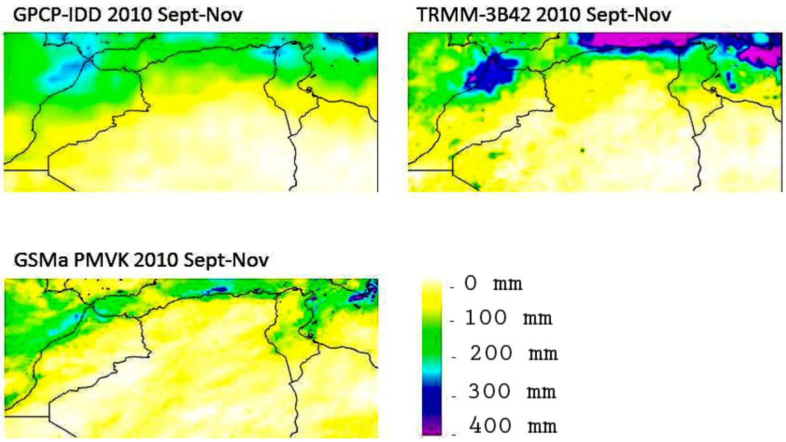

Fig. 1. Cumulative precipitation (in mm) between September to November 2010 witch GPCP-IDD, TRMM-3B42 and GSMaP product

This is not a minor effect as this area contributes a lot to Morocco intensive agriculture. On the same 3B42 product, a huge discontinuity can be observed between the coastal area and the open sea. This discontinuity could be related to different microwave algorithms between land and sea but is more likely linked to the rain gauge integration effect. The GSMaP displays a finer spatial structure but is almost everywhere lower than the two other products. In the arid area the three products show very different patterns hardly relatable to rainfall distribution. More specifically, the 3B42 shows isolated rainfall kernels in the South West. Two of them (A, B) correspond to highly reflective desert surfaces while another one (C) is collocated with Anti Atlas edge line. That does not mean that rainfall estimation is necessarily wrong but that these types of areas correspond to known biases of microwave estimation.

3.2. Rainy event from 10 to 12 October 2010

On October 9th, a cold pool is located on Spain (Fig. 2). The atmospheric flow is first southward, then changes eastward during the 10th and produced heavy rainfall in France (Roussillon). This episode is characterized by strong precipitation in Northern Morocco: Tangier (77mm, the 9, 26mm the 10), Laroche (38 mm the 9, 31mm the 10), Chefchaouen, (36 mm the 9, 91mm the 10) and in Northern littoral Algeria on 10 and 11 October: Beni Saf (180 mm); Sidi Bel Abbes (220 mm); Mostaganem (217 mm).

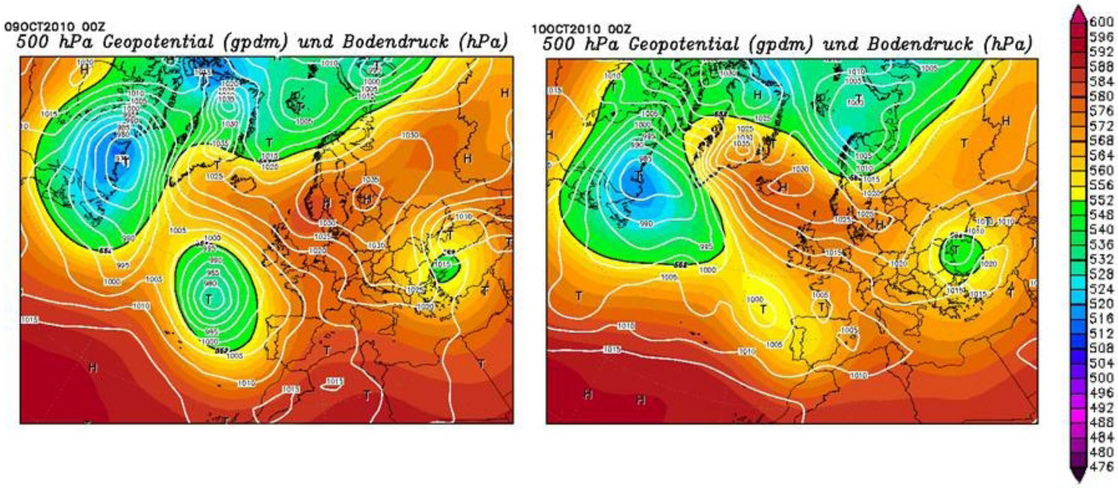

Fig. 2. NCEP Reanalysis for 500 hPa Geopotential (in gpdm) and surface atmospheric pressure the 9 (left) and 10 (right) October 2010 at 0h UTC in Europe, East Atlantic and North Africa (URL http://www.wetterzentrale.de/)

In Northern Algeria, the two NASA products (GPCP and 3B42) differ only by their spatial resolution (Fig. 3). However, the rainy area is located on different sides of Atlas Mountain: on the West for 3B42 (the most compliant with ground station observations) and on the East for the GPCP.

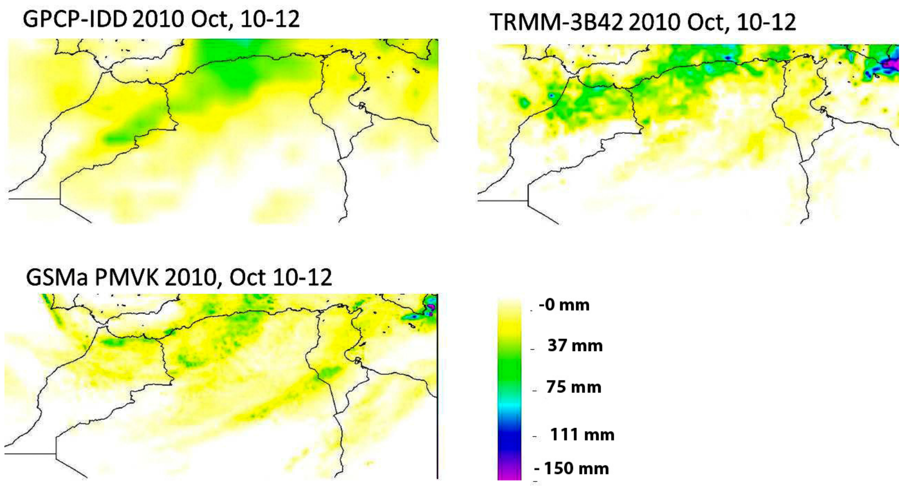

Fig. 3. Comparison of precipitation between 10 to 12 October (midnight) 2010 (midnight)

This difference highlights the errors introduced by the GPCP downscaling algorithm. Although GSMaP retrieved precipitations are globally weaker, the whole organization of the rainy belt displays the same spatial structure than the 3B2. A precipitation spot is located on the Choot El Jerid (Tunisia) Tozer (9 mm the October 11).

3.3. The early November 2010 floods in North-Western Algeria

During this episode, the passage of several cold fronts in South Southeast explain the origin of important rainfall and damaging floods in northwestern Algeria, mainly the north coastal regions around Hodna (1902 m) and Nemencha (1450 m) Mountains (Fig. 4). On November 1 and 2 Bouzareah (260mm), Bejaia (168mm) or Tiki-

Ouzou (249mm) received significant rainfall. Rainfall, usually in the form of thundershowers, has affected 10 provinces of the East (Skikda, Annaba, Constantine ...) during November 1st-4th.

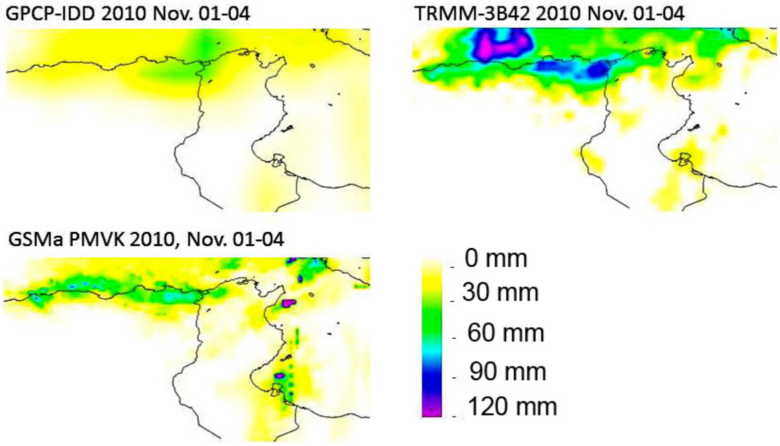

Fig. 4. Comparison of cumulative precipitation between November1 (midnight) to 4 (midnight) 2010

The three products display a spatial extension of the event that is coherent with ground observation. But global rainfall amount on this area are deeply different: from GPCP with the lower value to 3B42 with higher. The 3B42 quantitative estimation is the closest to rainfall amounts registered in Algeria. However the GSMaP delineates much more properly the event in Tunisia.

3.4. The late November episode in Northwestern Morocco

Heavy rains fell on 29 and 30 November especially on the North-West of Morocco, and the floods associated killed 31 people. 175 mm of rainfall fell in a few hours in the areas between Chefchaouen (99mm) and Larache (75mm) (Fig. 5).

The GSMaP high rainfall intensity spot corresponds to the Tanger-Tétouan region of flooding. On the other side the 3B42 estimates a large and homogeneous high rainfall zone. This is clearly an overestimation as such a rainy event should produce much more damages on all northern Morocco. The analysis of this bias is not straightforward but it can be assumed that microwave algorithm has been confused by the snow covering the edge of Rif and Middle Atlas mountains. This confusion could induce an error in rainfall duration estimation.

Agadir region experimented significant rainfall (45 mm in two days at the airport). Here again, the GSMaP estimation is more accurate than the 3B42 one. On the sea the comparison gives opposite results regarding the first event (1- 4 Nov. 2010). The GSMaP estimates higher values on a belt along the coast.

3.5. The Alger flood on 2001, 10 and 11 November

In Alger, heavy rainfall on 9-10 November 2001 caused human casualties (781 killed and 115 missing) and material damage (3271 buildings destroyed or damaged), the majority of this damage occurred in the Bab-el-Oued (western part of Grand Alger). Bouzaréah station recorded 263mm between November 9 at 19:30 and November 10 at 10am. The western part of Greater Algiers has undergone one of the most significant flooding that occurred in the Mediterranean during the last decade. 45 km south of Bouzaréah, rain gauges collected only 23 and 26mm on the same time interval. These values are consistent with estimates provided by the three products (approximately 20 to 40mm to the West of Algiers (Fig. 6).Certainly, the considerable damage cannot be only explained by the intensity of the meteorological event, as human activities (inadequate land use, uncontrolled urbanization) are largely responsible for this disaster (Menad & al., 2012).

One day before the 9-10 November flood, a deep altitude thalweg, causing a fast meridional circulation, crossed

France. On November 10th, this low geopotential was isolated in the South of the Balearic Islands and has spawned a very active cyclogenesis in the North of Algeria. On the coastal areas, the on-surface pressure was around 1015 hPa but it quickly decreased (1006 hPa on 11/9 at midnight). Several convective clusters therefore formed on the Mediterranean coast, from Morocco to Algeria. The 3B42 and GSMaP properly estimate the rainfall accumulations over the sea in the North-West of Algiers, but not those associated with localized heavy rainfall in Bouzaréah. The algorithm used in the precipitation products have an actual resolution coarser than these corresponding to the convective area with heavy rainfall. This shows one of an essential limit of global rainfall products.

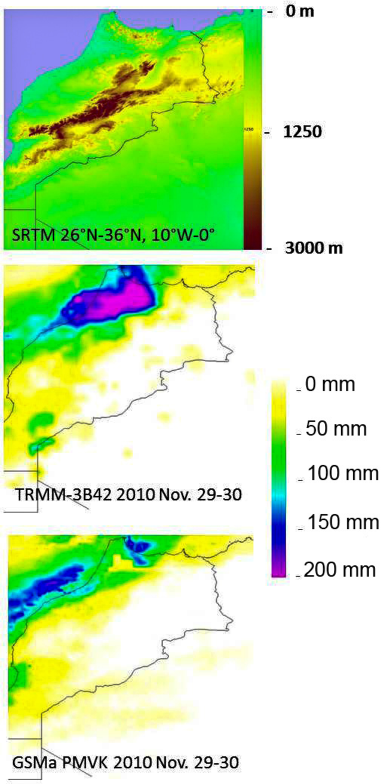

Fig. 5. Topography and comparison of cumulative precipitation for 3B42 and GSMaP between November29 (midnight) to 30 (midnight) 2010

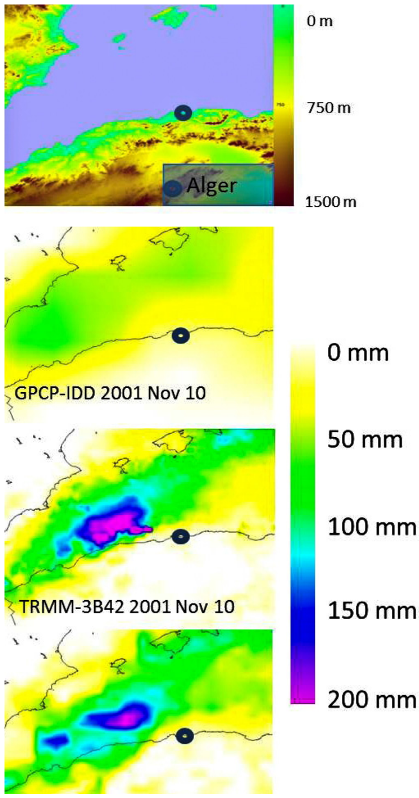

Fig. 6. Accumulated precipitation November 10, 2001 in the Algiers region

4. Conclusion

The present work emphasizes the difficulty of comparing satellite estimation methods. Product quality is heavily dependent of the type of rainy event. A comparison carried out on a longer period integrates different type of estimation error and therefore depends on the meteorological history of the period. The GSMaP, which is a pure satellite product, is sometimes more accurate than the NASA products, which integrate rain gauge data. This does not mean that ground networks are not important, but that designing an efficient assimilation algorithm is still an open issue. Obviously, all the global estimators are useful data to produce regional rainfall maps. However, on a finer scale, 3B42 and GSMaP perform better. But even these products can get significant biases when retrieving a specific event. A good knowledge of the design of the estimation method is necessary to interpret properly these fields at a fine scale.

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